Geological Report on the Valley of the Spiti, and of the Route from Kotghur. By Capt, HUTTON, *37th N. I.*

[The paper now published, completes a series of notes of a journey to the Spiti Valley, undertaken on account of the Asiatic Society, by Capt. Hutton, 37th Regt. N. I. It was with those which have already appeared placed at the disposal of the Editor of this Journal by the Committee of Papers. The results of the author's geological observations have induced the adoption of theories, upon which the Editor is only competent to remark in so far as the identification of the opinions of a publisher is concerned with those of any writer, to whom he is enabled to offer a medium of communicating his views to the public.

In the belief that hardly any novel theory could be broached, which would be unproductive of good results, (if not by its intrinsic merits, at any rate by the consequence of the discussion it might excite,) the Editor has great pleasure in giving publicity to this paper, for the views contained in which the author is alone answerable.]

The valley of the Sutledge is that portion of the western Himalya which, as its name implies, forms the tract of country through which the river Sutledge flows.

The term *valley* is however scarcely applicable to it, since it is strictly speaking nothing more than a deep and rugged mountain glen, of more than ordinary sternness and magnificence, often affording from the abrupt rise of its rocky sides, a mere channel for the roaring torrent which winds its irresistible and headlong course along its sheltered bed.

On either side rise high and snow-clad peaks, forming along the river's course two mighty walls, whose dark and furrowed sides proclaim the constant warfare which is waged by frost and heat alternately.

Villages are numerous along the river's course, sometimes placed near the water's level, at others raised high above it on the mountain's side, surrounded by their cultivation cut in steppes, and sheltered by the stern and frowning cliffs which raise their hoary summit far above it.

In the lower part of the valley, commencing from Rampore downwards, to below Kotgurh, vast beds of rolled and water-worn stones are seen accumulated on the river's banks, and rising high above the water's present level. Such deposits evidently owe their origin to the eddies or back waters of some far mightier stream than that exhibited by the Sutledge in the present day, even at its greatest height, and must undoubtedly have been formed by the rush of water attendant on the outburst of some enormous lake or *lakes* in the higher portions of the hills.

These deposits extend in many places along both banks of the river, and appear to have been formerly one solid mass of debris, which as the waters gradually disappeared, have become divided by the current of the stream.

These are for the most part situated at those places where the Sutledge takes a rapid turn, and have been evidently thrown up *within* the elbow by the eddies, or back waters.

On the surface of these broad and flat alluvial deposits, now flourishes an abundant cultivation, consisting of barley, wheat, rice, tobacco, poppies, &c. which being situated high above the river's level, are irrigated by the minor streams, which are furnished from the heights above them.

Higher up the river's course the valley narrows, and forming in many parts a mural cliff on either bank, gives a mere passage to the foaming stream, which rushes with a hoarse and deafening roar over the boulders which obstruct its progress, and dash its waters in muddy waves on high. Some hundred feet above the stream the hills are clothed with dense and stately woods of oaks and various sorts of pines, among which the "Ree," producing the edible seed called by the people "Neoza," is in great abundance. Above the belt of wood, are seen to rise huge rocky spires, along the rugged line of mountains, bare of all vegetation, and crowned by everlasting snows. From these snow-clad heights are furnished numerous streams, which rushing downwards in a sheet of foam, furrow the mountains sides with minor glens, and join the Sutledge as it rolls along below. Now and then the forests cease, and wide grassy tracts succeed, affording pasture to multitudes of goats and sheep; while here and there the whole hill side has slipped away, and left a mural height of precipitous and crumbling rocks, which are annually precipitated into the depths below by the expansive powers of the frost and snow.

The general features presented by the Geology of these hills, may be briefly and summarily comprised in the following observations :—

The main or central range of the Himalya or true snowy mountains, runs in a general direction from East-South-East to West-North-West, sending off branches or spurs in every direction, intersected or divided everywhere by deep and precipitous valleys, whose narrow bed or bottom almost invariably serves as the channel of some mountain torrent or rivulet, whose waters are supplied from the snowy heights above. Where the sides of these valleys are of sufficient elevation to retain the snow throughout the year, these rivulets receive a neverfailing supply of water; but, on the other hand, if the enclosing walls are of moderate or medium elevation, the vallies are often dry for several months together.

The vallies, it must be borne in mind, are not to be attributed, as some have contended, to the gradual wear and tear of the weather, and the streams which now drain through them, but have been formed by the convulsive uprise and disruption of the lofty mountains which form their sides; the glen or valley being thus a mere ravine or trough lying between them, and furnishing often just room sufficient for the passage of an insignificant stream.

The existence of the valley is not therefore to be attributed to the abrations caused by the constant action of the waters; but, on the other hand, the presence of the rivers and streams within them is entirely owing to the configuration of the mountains, which furnishing on the heights vast beds of snow, are ever sending down supplies, which naturally gather in the hollow troughs below, and gradually wind their way to form a junction with some larger stream, which in its turn seeks out the noble rivers of the plains.

It would therefore appear, that the existence of these hill streams is altogether owing to the previous formation of the vallies by the uprise of mountain ridges, the intervention of a glen or *khud* being the natural consequence of disruption in a range, or the sudden alteration of direction of the upheaving power, thus often causing ranges to intersect or to run parallel with each other. Thus the vallies are in no wise the consequence of the unceasing action of the streams, which now find a fitting channel in their depths.

In the present day, these glens usually communicate or open into some other, and the waters gradually escape, but doubtless time has been when their enclosing barriers were continuous, and numerous lakes were formed, until the weight of waters accumulated from the melting of the snows, burst through the rocky walls and so escaped. This is indeed a fact and no wild theory, for the people of different parts of the hills still hold traditions of such events. Dr. Gerard, I think it is, who mentions, that the natives informed him the valley of the Buspa was once closed at the lower extremity, and contained a lake, traces of which may still be seen along the banks of the present stream. A similar lake once occupied the glen in which the town of Soongnum now stands, and thick alluvial deposits containing rounded pebbles may still be seen in some of the higher parts of it; from the lower portion they have been swept away by the out-rush of the waters.

Of this, however, I shall speak again hereafter. The dip of the strata is, as might be expected in such a vast and often confused assemblage of mountains, excessively variable; and although previous travellers have uniformly insisted much on a N.E. dip, it will be quite as often found

to lie in an opposite direction. The prevailing inclination of the strata may therefore be said to be N. E. or S. W. It is, however, remarkable that the latter dip, although perceptible on both sides of the snowy range, is more prevalent on the northern than on the southern side. It has also been pointed out as matter of astonishment, that while one aspect of the mountains presents a gradual and shelving face, rich in soils and forest scenery, the opposite exposure is, on the contrary, found to present a bare and often mural cliff. This, however, is no just cause for astonishment, as the circumstance where it occurs is simply owing to the outcrop of the strata being on the precipitous side, while the dip of the other forms a more shelving slope. But this circumstance is by no means confined to any one direction in particular, for the outcrop of strata is no more prevalent on the northern than on the southern or any other exposure. It may, however, be taken as a general feature in all mountains, that while the dip or inclined position of the strata gives on the one face a shelving surface for the growth of plants, the other face or outcrop must necessarily be rugged and nearly barren, as furnishing by its precipitousness no resting place for soils. In this respect the Himalya does not differ from other mountain ranges. Travellers, however, having no knowledge of geology, and witnessing these facts, have sought to solve the problem by bringing to their aid supposed peculiarities of soil, of aspect, or of climate.

Viewed at a distance from the plains of India, these hills appear to form one long continuous chain or ridge, entirely clothed with everlasting snows, and this line has been designated by way of pre-eminence or distinction, by the name of the "snowy range," or "region of perpetual snows." Arrived within the mountains, and perched aloft upon the summit of some portion of this mighty range, the traveller is surprised to find that what he had been led to consider one continuous field of snow, is nothing more than a vast assemblage of scattered and far distant peaks, approximated apparently by the distance at which they were wont to be viewed into one wide-extending line, and forming component parts of the same snow-clad range.

He is surprised to find the greater portion of that line to be absolutely devoid of snow during several months of the year, except within the deep and sheltered glens, to which the rays of the summer sun can only penetrate for a few short hours during each day, and where frost resumes its sway the moment his beams are withdrawn or intercepted by some towering peak.

Far beyond the ridge which he has hitherto been accustomed to distinguish as the snowy range, he now beholds gigantic and frowning masses clothed in the winter garment, rising often in isolated peaks to

an elevation exceeding that of the main or central chain on which he stands.

Around him, far and wide, he beholds these rugged and awe-inspiring peaks rising pre-eminently grand amidst the sea of mountains by which he is surrounded, and he now first learns that the line of snow he has witnessed from the plains, is the wintery sheet which envelopes these often widely separated masses, but which to the eye of the far-off observer, have become blended by the distance into one long line of continuous snowy peaks.

The central range, and all the hills, with the exception of these loftiest peaks and some deep secluded glens, usually lose the sheet of snows during the period that the monsoon is raging in the plains. It is at this season that the snows send down the greatest supplies of water to the rivers, commencing about the end of May and continuing till September, when the frosts again arrest the dissolving snows, and the mountains once more put on the pure and dazzling robes of winter, and continue thus enveloped in one sheet of snows until the approach of summer again relieves them.

No sooner has the wintery garment disappeared, than a fine rich sward at once springs up, almost as if by magic, so rapid is the vegetation in these high tracts,—affording abundant pasture to the flocks and herds, which then range over them to the height of 15,000 feet above the sea.

This smiling and verdant state of things is, however, unhappily of short duration, appearing like the transient gleam of sunshine that often precedes the fiercest storm, yielding in the space of two short months to the drifting whirlwind and wreaths of snow, that soon enshroud the whole in cold and dreary solitude.

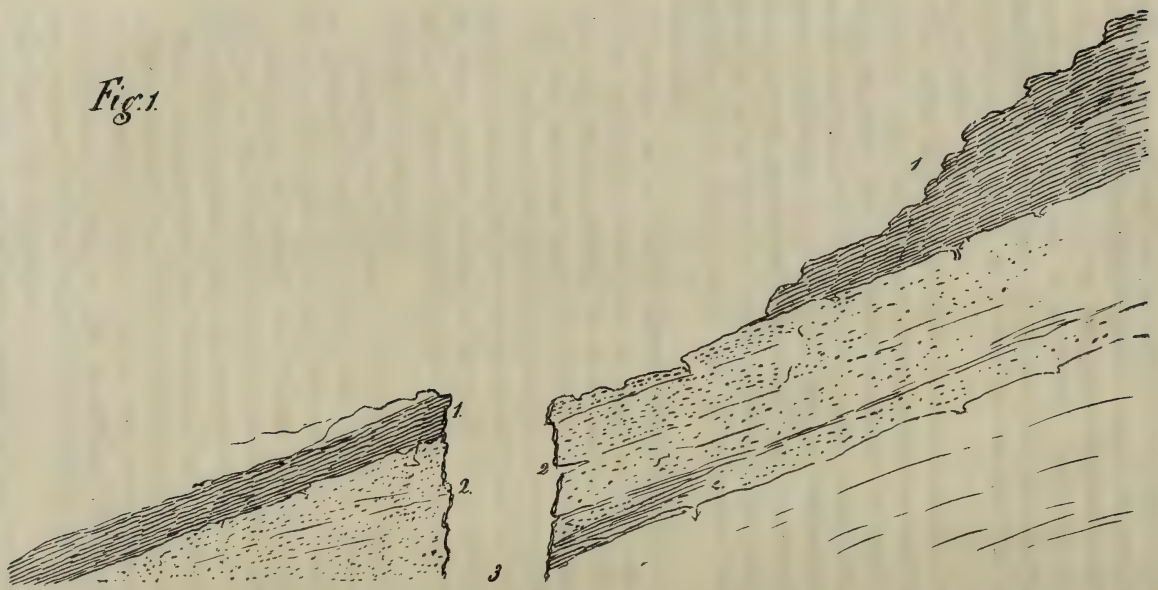
Journeying from Kotgurh, in the lower hills, towards the Spiti valley, the geological formations which came under my observation from that station to the frontiers of Tartary, were exclusively of the primary class.

Commencing at Kotgurh, and crossing the brow of the hill above Kaypoo, we find strata of *mica* and *hornblende schists*, jutting up through the surface, interspersed with veins and nodules of *quartz*.

These veins are often found to contain *iron* disseminated in small thin scales resembling *mica*, and in such cases the *quartz* is generally in a state of decomposition. This ore pays no duty to Government, and the mines, if indeed such they can be called, are seldom worked, being so unproductive, that out of 14 lbs. weight of the rough ore only 2 lbs. of iron, and that impure, can be procured.

Veins and masses of coarse primitive *calc spar* or *carbonate of lime* are also seen to accompany the *mica slate*. These rocks continue, with an

Fig. 1.



occasional bed of *porphyritic gneiss*, until we reach Rampore, half a mile beyond which a fine white *granular quartz* occurs, underlying *mica slate*.

These strata dip strongly to the N. E., and are seen on either side of the river, by which they appear to have been transversely divided, the lower end dipping down on the right bank, while the upper portion forms a high mountain on the left.

I say these strata have been *apparently* divided by the Sutledge, which now flows through them, because such *in reality* has not been the case; but the bed of the river lying through them, is entirely attributable to the disruption of the strata at this point having formed a fitting channel for the waters to escape through to the plains.

(See plate)—Fig. 1.

1. 1. *Mica Slate.* 2. 2. *Granular Quartz.* 3. *Bed of Sutledge.*

The surface of this *quartz rock* takes a yellowish rusty hue when exposed to the weather, but when freshly fractured, it is of a pure white, somewhat resembling Carrara marble in appearance, but of a coarser texture.

Onwards from Rampore, the *mica schist* is seen in several varieties, sometimes appearing to be composed entirely of *mica*, at others containing a predominance of *quartz;* in these cases the strata are either soft and crumbling, from the *mica* scaling off, or very hard and flinty, from the quantity of *quartz*.

Silvery mica passing into *chlorite schist* is abundant near Goura, and from its soapy and decomposing nature, the whole rock has in many places slipt away altogether, leaving a constantly decomposing cliff, from which in wet weather large masses are constantly falling.

Further on, the *mica* is seen to contain numerous small crystals of *hornblende*, which cause it to pass gradually into *hornblende schists*. *Garnets* of small size occur occasionally imbedded in the *mica*, which also contains masses of *white quartz*, in which beautiful crystals of *cyanite* are interspersed, varying in shade from pale sea green to bright blue.

The characteristic rocks, however, from Kotgurh to Sarahun are *mica* and *hornblende slates*, frequently alternating with each other, and imbedding blocks of *porphyritic gneiss* and *white quartz*.

From Sarahun the *gneiss* begins to shew itself as the prevailing rock, and occurs both common, red, and *porphyritic;—mica slate* and *hornblende* are also frequent, and when they come in contact, the *mica* often becomes jet black.

A few miles from Sarahun, on the right bank of the river, an interesting appearance presents itself in the disposition of the strata. The dip which up to this point has been pretty uniformly to the N. E., now gradually rises, and preserving for a short distance a nearly horizontal position, at last lifts itself abruptly, and dips back again to the S. W. at the same angle of about 45°.

From this disposition of the strata it becomes evident, that they have been lifted or upheaved at both ends, from the horizontal position they once had, by some volcanic force. The lowest strata exposed to view at this spot are on the right bank of the river, nearly even with the water, and form a complete arch immediately under those strata which dip to the N. E. I annex a slight sketch made on the spot, which will serve to show the position of the rocks, better than a description. *(See plate)*—Fig. 2.

Beyond this, as we approach Traada, a fine white *granite* is observed, containing large scales or crystals of *mica*, and farther on still, about Nachar, *white felspar* becomes abundant, imbedding the same *mica* crystals, and forming the first division of the *granite* of some geological writers. *Quartz* also occasionally entered into its composition and formed true *granite*, with which were found *hornblende* and *mica slates, porphyritic* and *granitic gneiss*. In some instances where the *hornblende* and *granite* were in contact, the *mica* of the latter rock assumed a black and glossy appearance, producing a variety of *granite* of some beauty.

Proceeding from Nachar, the road passes over formations similar to those already mentioned, and a few miles lead down to the Sutledge, which is crossed by a good broad *Sangho*. At this point the rocks rise abruptly in huge masses on either side, confining the river to narrower limits, and affording a mere passage for its waters.

These rocks are of *gneiss*, and the stratification which previously had often been indistinctly discernible, now ceased altogether, and the beds presented a shattered and amorphous mass,—a circumstance by no means of rare occurrence among this class of rocks.

From the *sangho* to Chergong the road still continues along the bank of the river over beds of boulders and broken rocks of every size, consisting of *granite*, *gneiss*, *mica*, and *hornblende slates*. Here too *cyanite* again occurred in *quartz*, and crystals of *crysoberyl (?)* in *granite*.

From Chergong to Meeroo the strata of *gneiss* are often laid bare by the descent of streams from the snows above, and the dip is seen falling to the N. E. at about the usual angle of 45°. Beyond this place occur thick beds of *mica slate*, containing *garnets* in profusion, and often, from the decomposition of the rock, the whole road is strewed with *garnets* of various sizes. Beneath this bed occurs one of *white quartz rock*, which is seen rising from the edge of the Sutledge to about 3,000 feet in thickness.

Fig: 2

Near Chini, the *mica slate* contains occasional small crystals of *cyanite*, and sometimes passes into *chlorite slate*.

A short distance from Chini, the whole hill side has slipped down into the Sutledge, from the action of frost and snow, and the cliff now towers up from the banks of the river, presenting a sheer and perpendicular wall of between six and seven thousand feet in height. This vast mass is composed throughout of *gneiss*, and the road, which is a mere scaffolding, passes along the face of it, at 4,000 feet above the Sutledge, which is seen foaming below.

From this to the village of Leepee, the formation is pretty nearly the same, consisting of *granite*, *gneiss*, *hornblende*, *mica*, and *quartz*.

The *granite* about Punggee, Rarung, and Junggee, contains a large proportion of *hornblende*, and at Rarung it is also seen to assume a brick red colour, often traversed with veins of *quartz*, both red, amber, and white. The red *granite* appears only in masses imbedded in a yellowish variety, which is the true rock, and which towards Leepee gives place to *gneiss* and *mica slate*. Above the last mentioned rock commences the first bed of *argillaceous slates*, which continues interstratified with *greywacke schists* to the top of Roonung Pass. The alternations of these strata are frequent, sometimes the one and sometimes the other rock prevailing in thickness.

These beds are evidently the first indication of the transition, or lowest secondary formation of geologists, and extending across or through the Roonung Pass, downwards to Soongnum, they are seen to support strata of compact *greywacke*, and beds of *quartzose* rock, apparently analogous to and holding the place of the *old red sandstone* of Europe.

The town of Soongnum stands in a valley immediately between the Roonung Pass in its front and the Hungrung Pass in its rear. In front, the range of hills which form the right side of the Rushkoolung valley are composed of an *argillaceous* series, consisting of *clay stones* and *greywacke slates*, of different textures and degrees of induration, and dipping to the S.W. The strata in the rear of the town, forming the left bank, dip, on the contrary, to the N. E. and are composed of *greywacke slates*, compact *greywacke*, *old red sandstone*, and a superior stratum of *limestone* and *greywacke*. These towards the summit of the range gradually change their dip, and rise up again to the S.W., the whole being surmounted by a bed of dark blue secondary *limestone*, containing portions of *clay* and *silex*. This formation extends along both sides of the Rushkoolung valley, even to the Manerung Pass above Manes in Spiti, a distance of about seventeen miles. About seven miles from Soongnum, copper veins occur in their strata of white *quartz* rock, and *veinous quartz*, lying occasionally between, or ramifying through, the *greywacke* and *old red sandstone*. The

last mentioned rock varies much in colour and in texture, the lowest stratum being *white*, and scarcely distinguishable from *quartz* rock, but changing gradually to a faint tinge of *pink*, becoming deeper as it passes upwards, until its colour is of a dull *purplish* hue.

These strata are sometimes separated by a very thin layer of soft whitish *marl*. The crest of the Hungrung Pass is 14,837 feet above the level of the sea, and is composed of dark blue *limestone*. The range on which this Pass is situated divides Kunawur from Hungrung,—a district inhabited by Tartars, who are subject to Bussaher.

Descending from the Pass to the village of Hungo, the road passes over numerous alternations of blue *limestone* and *greywacke slates*, resting upon white *quartz*, which lower down gradually passes into a greenish variety of the same rock.

These strata all dip to the S.W., and are probably an outcrop of those which run in a N.E. direction from behind Soongnum, and thus shew the effects of what may be termed a *double upheavement*, or lifting of the same strata at two different points. The lofty *granitic* peaks which tower up to the right of the Pass, at once shew that they have been instrumental in forming the S.W. dip, and it is more than probable that the same rock might be discovered also protruding through the strata on the opposite exposure.

The following *partly* imaginary section of Hungrung, may serve to explain my meaning:—

(See plate)—Fig. 3.

Supposed Section of Hungrung Mountain.

Strata of *greywacke slates* are met with for a few miles after leaving Hungo; but they disappear as we approach Leeo, or rather, from the great descent of the road, they are left far above, while the base of the mountain is found to be a dark coloured *gneiss*, traversed and intersected in every direction by veins of white *quartz*.

Leeo stands in a kind of basin, surrounded on all sides by lofty hills of *granite* and the same dark *gneiss;* but the lower parts of them are overlaid by strata of the secondary series, consisting chiefly of *greywacke* and *shales*. On the sides of the surrounding hills exist strong indications of the former presence of a lake, in the lines of water-worn stones and pebbles that now rest many hundred feet above the river Lee.

These appearances were long since pointed out by Dr. Gerard, who though knowing nothing of geology, was at once forcibly struck with

Fig. 3.

1.1. Greywacke Slate.— 2. Compact Greywacke. 3. Old Red Sandstone
4. Strata of Greywacke and limestone 5.5. Blue Limestone.
6. Strata of Limestone and Greywacke. 7. Quartz Rock - white and Green

the conviction, that nothing but the former presence of deep waters could account for the phenomena here so plainly exposed to view.

In his conjectures on this head, that enterprising and unwearying traveller was undoubtedly correct.

In the bed of the Lee, where it is crossed by a wooden *sangho*, a thick bed of white *quartz rock* is seen dipping to the S.W., and as we mount the hill in the direction of Chungo, beds of *boulders*, and disjointed masses of *granite*, *gneiss*, and *mica slates* hurled from above, are passed over, now in many places overlying the secondary *shales*.

At the village of Chungo, which is the last on the left bank of the Lee, under the government of Bussaher, the most decided indications of the former presence of a deep lake again occur. To the eastward of the level patch on which the village and its cultivation stands, rise three lofty and rugged mountains, whose shattered sides present sections of the same strata as those noticed at Leeo: namely, deep beds of dark *gneiss* and *mica slates* intersected by *granitic* and *quartz* veins of various thickness; these strata dip down towards the west, and as they approach the village, are lost beneath the vast accumulations of alluvial soils, which here, as at Leeo, mark the former presence of deep and tranquil waters.

To the southward these deposits consist almost entirely of thick beds of *clays*, *sands*, and *boulders* of every size, rising high above the level of the village; while to the NNE. are again presented the same alluvial deposits of a greater thickness, and accompanied in addition by a deep and extensive bed of a pure white and friable *gypsum*. This bed is perhaps a most valuable discovery in a geological point of view, as tending to show the nature of the waters from which it was precipitated. This thick *gypseous* bed is overlaid by the *sands*, *clays*, and *boulders*, which have already been noticed. At the fort of Skialkur, on the opposite or right bank of the river, about 3½ miles from the village of Chungo, this *gypsum* is likewise seen overlying the transition series of alternating *shales* and *sandstones*.

These deposits are now at the height of 2,000 to 2,500 feet above the present level of the river's course, or at an elevation of 12,000 to 12,500 feet above the level of the sea.

The three mountain peaks of *gneiss*, which rise up to the eastward of Chungo, are divided from each other by narrow glens, through which streams flow down to join the sea, between which and the base of these mountains, the whole alluvial deposits have been swept away, and the present cultivated plain of Chungo is therefore situated far below the surrounding alluvium, which rises like walls on either side of it.

As we proceed from Chungo towards Spiti, the road lies at first over the alluvial accumulations above-mentioned, for two or three miles, when from

the abrupt nature of the primary rocks that are hence met with, they cease to exist, except far below where a wide and shelving plain lies along the river's side, and which is entirely composed of them. From the point where the road leaves them behind, for a distance of six miles, the strata are again of *mica*, *slate*, and *gneiss*, varied with the same carious veins of *granite* and *quartz* as those of Leeo and Chungo. At this point the mountains are separated by a rapid river called the Paratee, which runs down from Chinese Tartary and joins the Spiti near Skialkur. Here the primary series may be said to disappear, and the Spiti road crossing the Paratee by a natural bridge of stone, which is formed of several large masses of *gneiss* fallen from above, and wedged firmly together over the stream, brings the traveller at once upon the secondary class. The lowest strata are therefore just perceptible where the waters cut their way through, and we thus catch a glimpse of the *gneiss* of the opposite bank, above which occurs a *talcose schist*, white *quartz* rock, and *clay slate*, dipping to the S. W. Above these are alluvial deposits similar to those of Chungo, and extending for a mile or two inland from the river, forming a flattened plain, on which stands "Kewrick," the first village of Chinese Tartary. Here again a portion of the deposit has been swept away by a descending stream, exactly as at Chungo. It is worthy of remark, that all these alluvial deposits are the deepest and most extensive when the surrounding hills have the most gradual slope, and where they retire so as to form recesses; while on the contrary, as might be expected, where the dip of the strata is rapid or acute, scarcely any trace is left of the former existence of a lake, because the deposit has been swept away by the outrush of the escaping waters.

These accumulations are likewise the most extensive at the lower end of the Spiti valley, where alone the *gypsum* is to be found. To this fact I would beg to call special attention, as it will be hereafter alluded to, and prove of some importance in the explanation of these *diluvial* and *alluvial* deposits.

From Kewrick the road runs over hills, which are entirely of the secondary class, being frequent alternations of the same rocks, as *greywacke* and *claystones*, *limestones*, and *sandstones*, and in one or two instances a trap of *greenstone* is also seen, both stratified and amorphous.

From Kewrick to the village of Larree, which is the first inhabited place in Spiti, we travel first for four miles over the edges of strata of *clay slates* and accumulations of *debris*. From the decomposing state of these strata, caused the effects of weather and a portion of *alum*, which causes them to scale off in soft flakes, the whole of the hills on either side of the Spiti river have a charred and blackened aspect, which combined with their arid and barren nature, gives a sad and melancholy appearance to the country, by no means cheering to the weary traveller.

The dip of the strata is now uniformly to the S. W., and generally at an angle of 45°, though here and there they rise abruptly to a nearly vertical position, denoting an excess of the upheaving forces from below. As we approach Larree after crossing the Gew river, the bed of which is of *greywacke slate*, we come upon a thick stratum of pure white *quartz* rock, which appears to be a continuation of the same rock which was seen at Leeo on the opposite side of the range; in contact with this, and immediately resting upon it, is another bed of siliceous rock, which passes gradually into thin strata of flinty slate. Upon this rests *clay slate*, which then alternates frequently with *greywacke* and *sandstones*. Further on we perceive masses of *gypseous breccia* formed of angular fragments of *argillaceous schists*, encrusted or cemented together by *gypsum*. This rock, if it be entitled to the name, owes its origin to the same waters which deposited the *gypsum* beds of Chungo and Skialkur; it is found overlying the edges of the true strata from which it has been formed, and occurs in rude and mis-shapen masses. To this *breccia* I would also call attention, as serving to shew a change in the waters of the lake, or at all events a decrease in the proportion of their *saline* properties. Farther on still, and nearly opposite the village of Somra, a stratum of trap is seen to occur between *shales* above and *sandstone* below; it is conformable to the true strata with which it is clearly interstratified, not causing any dislocation of the series. Beyond Larree, however, the same rock occurs again, in one place interstratified with *greywacke* and dark *blue limestone*, at another running up vertically in an *amorphous* mass through the strata, which it first dislocates and then overlies. In this case, the strata on either side of the Spiti dip to the S. W., while the rocks through which the trap has more immediately passed or been injected, are thrown boldly and abruptly from the usual course to the westward. The strata on the opposite side of the river are at the same time raised from the angle of 45° nearly to a horizontal position, and after some twisting of the strata, again with apparent difficulty regain their wonted S. W. dip. Here it is evident that the trap in question has been the molten vein whose struggles to burst upwards through the superincumbent weight of strata has been the agent which has thrown them into their present inclined positions, and in its upward course has first become partially interstratified with those which possessed the least induration or means of resistance, and then finally, as it burst through all obstacles, flowed over them in a broad sheet of molten matter, which as it cooled assumed the present solid and compact texture.

Of such having been the fact, we observe proof in the vein of vertical trap acting as a support, or upright as it were, from which the strata now incline and dip downwards.

As, however, trap is known to possess, "in a general sense, the universal common character of being unstratified, and posterior to the rocks with which it is connected,"* it becomes necessary in here stating, that it is conformable to and interstratified with those of the secondary series, to offer a few theoretical remarks on the probable means by which this partial stratification has been produced.

The interstratification of this rock, where it occurs, is of very inconsiderable extent, when compared with that of those with which it is associated, possessing by no means the wide and almost universal range of the primary and secondary series, but being on the contrary, "in a great measure limited to particular spots, more or less extensive, and to be, if separately considered, partial and independent productions."†

Let us then suppose that these secondary strata were once (which in fact they really were) horizontal deposits from the waters, which it is generally supposed were instrumental to the formation of the series to which they belong.

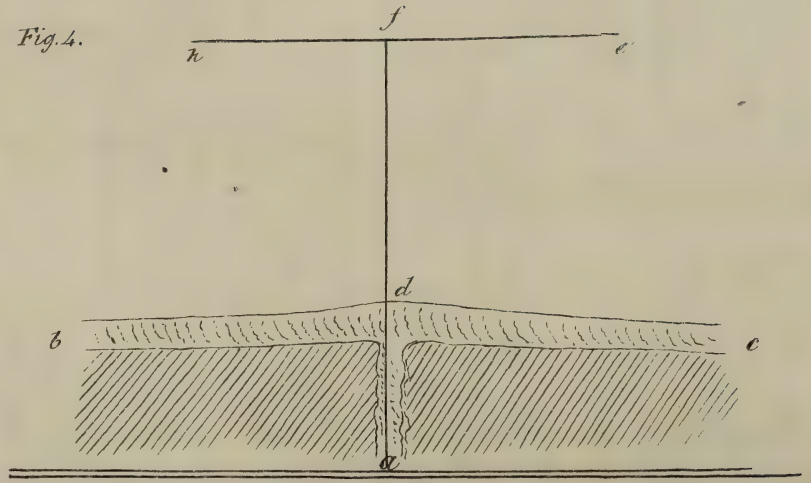
We shall thus perceive them to have been deep *unconsolidated* masses of sands, covered by muddy layers, which we now term *shales*. The struggles of the molten matter to procure access to the surface would, from the *heat* and *pressure* engendered by its upward course, have the effect of vitrifying and indurating the sands through which it forced a passage, and of converting them into strata of *sandstone*, while the *shale* or muddy deposit next in succession being lighter and less massive than the stream of trap, would probably rise and yield a passage between itself and the *sandstone* for the molten matter to form a stratum, somewhat in the same manner as oil would give place to a stream of water if injected through a tube or aperture below it.

The muddy deposit, however, being hardened by contact with the *lava* and by the general pressure of the uprising strata, would burst as the *sandstone* had already done, and yield a passage to the trap, which flowed through and overspread them at the surface.

Should it be contended that the outburst of a stream of *lava* such as that I have described the trap to have been, would have expended itself in a shower of ashes or cinders, rather than have assumed the stratiform structure it now exhibits, I would remind the reader that the secondary rocks are supposed to have been deposited in the bosom of a tranquil water, and that that water formed either extensive lakes or portions of the sea.

* † McCulloch's Geology.

Fig. 4.



The upheaving *lava* current had therefore not only the weight of the superimposed deposits, but the pressure likewise of an enormous volume of water. It becomes more than probable, therefore, that this aqueous pressure would effectually check the tendency to produce cinders and ashes, and thus as the stream poured upwards through the deposits and came in contact with the waters, the molten matter would extend itself along the bottom of the lake, and thus overlie the secondary strata, as in the present instance.

For farther information on this subject, I would refer the reader to *De la Beche's* Geological Manual, where will be found some very just and apposite remarks on the point in question.

"It being by no means probable," he says, "that the density of sea water beneath any depth which we can reasonably assign to the ocean, would be such as to render it of greater specific gravity than liquid *lava* ejected from a volcanic rent, situated beneath the sea, it would follow that so long as the lava continued in a state of fusion, it would arrange itself horizontally beneath the fluid of inferior specific gravity." The question then arises, how long a body of lava in fusion would remain fluid beneath the waters of the sea? The particles of water in contact with the incandescent *lava* would become greatly heated, and consequently, from their decreased specific gravity, would immediately rise: their places being supplied from above by particles of greater density and less temperature. Thus a cooling process would be established on the upper surface of the *lava*, rendering it solid.

Now as the particles of fluid lava would be prevented from moving upwards by the solid matter above, pressed down by its own gravity and the superincumbent water, they would escape laterally, where not only the cooling process would be less rapid, from the well-known difficulty of heated water moving otherwise than perpendicularly upwards, but where also the power of the fluid lava to escape resistance would be greatest. *(See plate)*—Fig. 4. Let *a* be a volcanic rent, through which liquid *lava* is propelled upwards in the direction *d f:* the *lava* being of greater specific gravity than the water *b h e c* it would tend to arrange itself horizontally in the directions *d b d c* The surface *b d c* having become solid, the *lava* would escape from the sides *b* and *c*, spreading in a sheet or tabular mass around; and this effect would continue so long as the propelling power at *a* was sufficient to overcome the resistance opposed to the progress of the *lava*, or until the termination of the eruption, if that should first happen."*

This clearly stated theoretic problem may now be successfully reduced to practice, and will correctly and exactly apply to the phenomenon under

* De la Beche's Geological Manual, p. 125.

consideration. The truth therefore of *De la Beche's* proposition will be at once established.

(See plate)—Fig. 5. Let us suppose these now inclined strata to be in their original horizontal position, and 2 and 3 forming beds of unconsolidated sandy and muddy deposits beneath the waters of the lake or sea *a c e h.*

Then *a a a a*, &c. is a vein of *lava* or molten *trap*, which in its endeavours to find vent, upraises and bursts through the solid primary series denoted at 1.

By the heat and pressure thus engendered, the *lava* indurates the sand at 2, and converting it into *sandstone*, breaks through it also, and is thus brought in contact with the muddy deposits represented at 3. This deposit being of a specific gravity inferior to the stream of *lava*, is naturally displaced and forced to contract and furnish room for a stratum of *trap* at *a a a.*

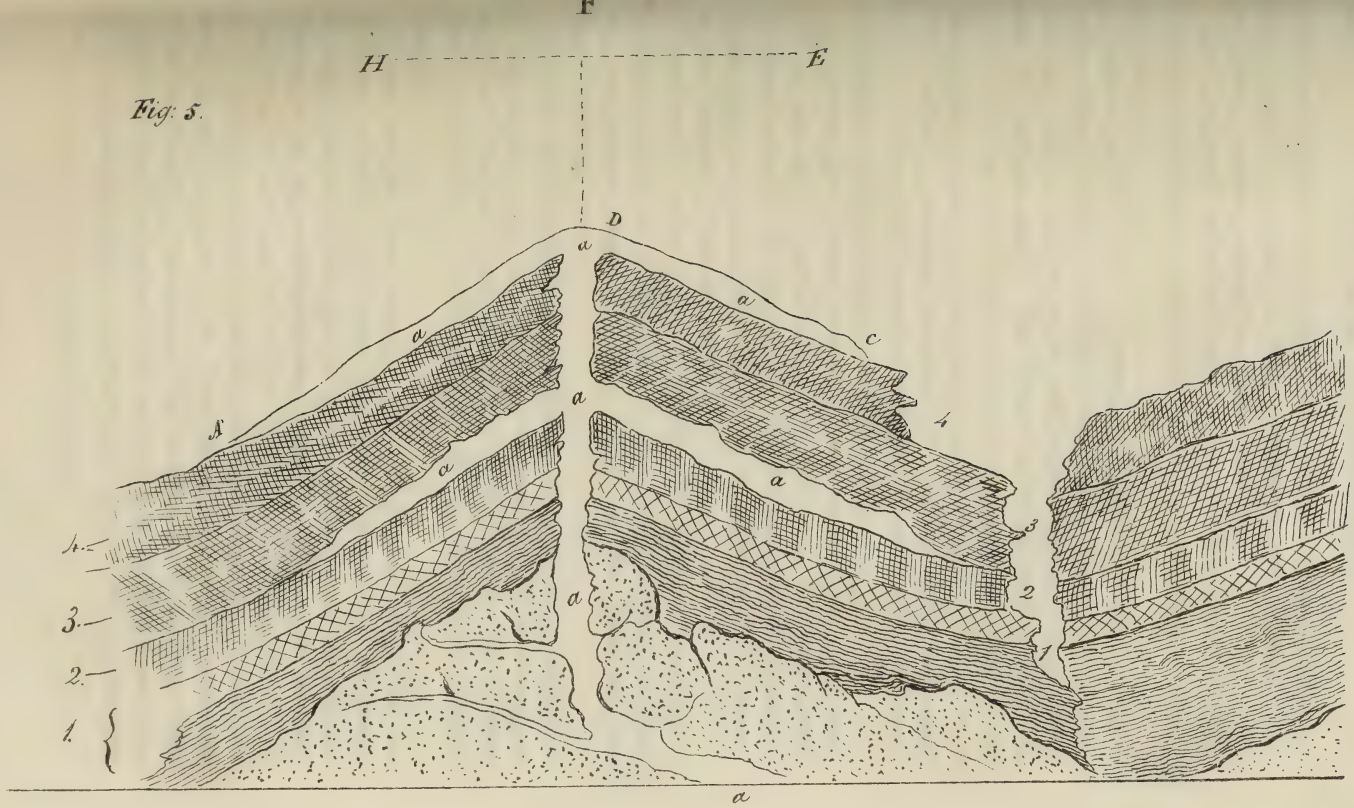
The heat and pressure, however, continuing, speedily and almost on the instant, converts the muddy deposit into *shale* or *slate clay.* And the lava current bursting through it and the superior stratum of *limestone*, comes at length to the surface, and in contact with the waters. Here then commences the facts detailed theoretically by *De la Beche*, as already quoted, and the stratum of *trap* spread over the surface of the now inclined and consolidated strata of deposits; while the waters of the lake or sea being displaced by the upheavement, effected an escape through the various channels afforded by the disruption of the uprising strata.

It may possibly be objected that the occurrence of a compact stratum of *limestone* above the *shale*, and in contact with the *trap*, will at once invalidate the theory here proposed, from its being a known fact, that when heat is applied to *calcareous* matter, the *carbonic acid* is driven off, and the remaining *lime* rendered infusible.

I shall endeavour therefore to obviate such an objection, by quoting and *establishing* a theory long since propounded by Dr. Hutton, which at the time of its proposition was looked upon as an ingenious, but perfectly untenable, doctrine.

"He had asserted that *calcareous* rocks, like every other, had been subjected to the action of heat. But it was well known that when heat was applied to this class of rocks the *carbonic acid* was driven off in the shape of *gas*, and the remaining *quicklime* become infusible. Dr. Hutton indeed had answered this by suggesting, that the pressure of the superincumbent ocean was sufficient to confine the *carbonic acid*, and to cause it to act as a flux on the *quicklime*. His theory, however ingenious, was so abundantly gratuitous, that it by no means satisfied even his own disciples. After Dr. Hutton's death, Sir James Hall ascertained by numerous experi-

Fig: 5.



ments that *carbonate of lime* might readily be fused when exposed to heat, if it were at the same time under a pressure not greater than Dr. Hutton's theory required, or about a mile and a half of sea."*

Now it is easily perceptible, that the result of these experiments is in exact accordance with the effects which the theory here proposed would give rise to.

We have supposed that the present solid strata were once soft and aqueous deposits beneath a vast depth of waters; we thus perceive a beautiful and conclusive illustration of Dr. Hutton's theory in the fact, that when the *heat* generated by the pressure and condensation from below acted on the superior *calcareous* stratum at 4, that very stratum was then actually subject to the pressure of the superincumbent waters at *A C E H*, which by preventing the escape of the *carbonic acid gas*, and causing it to act as a flux upon the *quicklime*, converted the stratum, as Dr. Hutton had suggested, into the compact state which it now exhibits.

As theoretic speculations, however just, and however much in accordance with the phenomena observable, they may prove to be, may nevertheless be deemed misplaced in a paper of this kind, I shall leave the subject for a more fitting occasion, and now pass on to a consideration of the remaining facts exhibited in the strata of the Spiti valley.

From Kewrick to the village of Leedung, the strata may be said to be of the same descriptions, namely, *talcose schist*, *quartz rock*, *greywacke slates*, *clay slates*, *sandstone shales* and *trap*, all except the last alternating frequently with each other.

A precise description of each rock belongs rather to the department of the mineralogists than to that of the geologists, and I therefore content myself with pointing out the series rather than individual species, in order that I may hasten on to the theory which the appearances presented suggest.

Passing therefore from Larree via Pokh to the fort of Dunkur, we find the strata to consist of the same alternations of rocks as those already mentioned; but at this latter spot the appearances denote a struggle for the direction of the dip, which merits some attention. The range of hills running along the right bank of the Spiti opposite to Dunkur have a N. W. by W., and S. E. and by E. direction, and at four miles below the fort the strata dip uniformly to the S. W. From that point, however, or near the village of Maness, it would seem that an upheavement had taken place through or along the centre of the range, causing the superior strata to assume a pent or roof-like appearance, throwing them on one side with

* Journal of Science, p. 4.

an acute dip to the N. E., while the opposite side preserved the S. W. direction at a less acute angle. In such cases where a section is obtained by a water course, the strata forming the heart or interior of the range are seen twisted in every grotesque direction. These strata consist of thick beds of *argillaceous schists* and *sandstones*, and what strikes one as singular in their disposition is, that the upheavement has had the effect of throwing the outcrop of the *sandstone*, or superior stratum dipping to the S.W., higher than the portion which falls to the N.E. Thus the joining of the strata is not at the summit of the range, but the rocks of the N.E. side are seen lying against those of the opposite direction, whose upper edge, or outcrop, juts out above them. *(See plate)*—Fig. 6.

Passing on from Dunkur we come to the Lingtee river, which joins the Spiti.

Here again a double upheavement of the strata appears to have taken place, which will be better understood by a reference to the annexed sketch, and which may serve as an example in all similar cases. *(See plate)*—Fig. 7.

On the right bank of the Spiti, the strata fall acutely to the river in a N. E. direction, as already pointed out, while on the left bank, although they at first dip to the same direction, they are seen first gradually to rise to a nearly horizontal position, and then to dip backwards again to the S. W. This occurs on the left bank of the Spiti and the right bank of the Lingtee at the point where the two rivers meet.

On the left of the Lingtee the strata first dip to the N. E., and then after many extraordinary twists and contortions, yield, as it were reluctantly, to the contrary dip, which turns them back to their old and proper direction of S.W.

In all these cases it will be found that the rocks are rent asunder, and the disruption now forms deep *khuds* or glens, through which at present a stream or river descends.

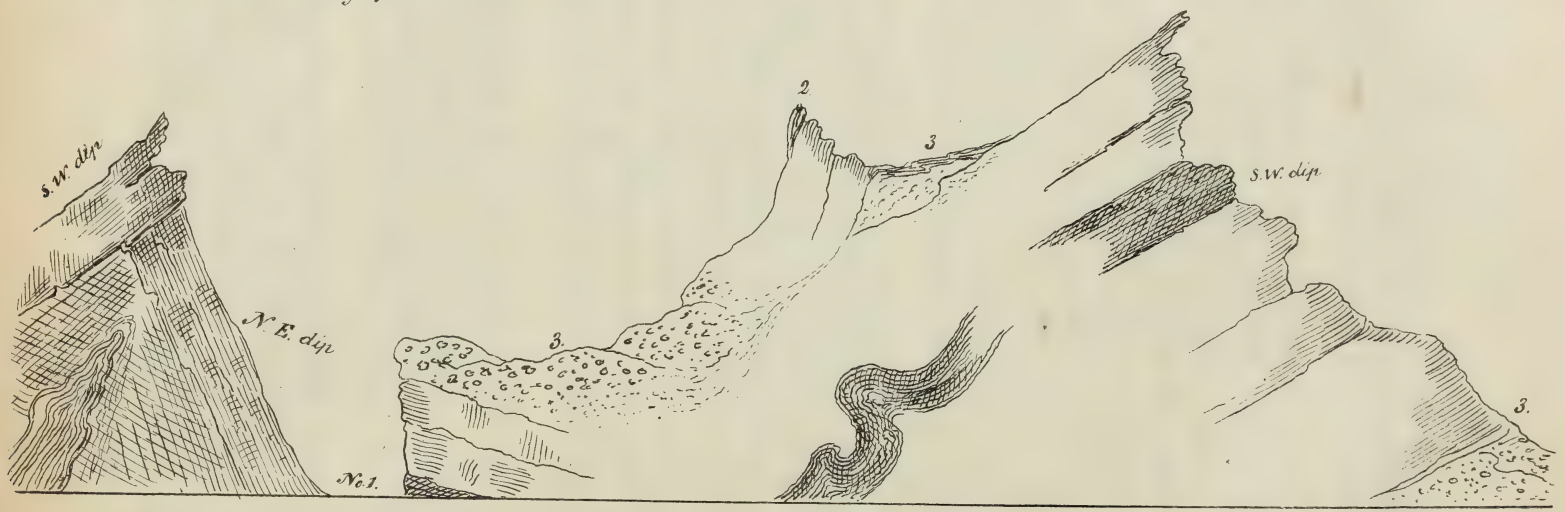
About six miles from Dunkur stands the village of Leedung, where the strata consist, in an ascending order, of *greywacke* and *clay slates*, dark blue *limestone shales*, *limestone* and *sandstone*, repeated in many alternations.

Leedung stands at the height of 12,037 feet above the sea, and the strata just mentioned rise precipitously above it to the height of from 3,000 to 6,000 feet more, or to 15,000 and 18,000 feet above the sea. The highest stratum here appeared to be of *sandstone*, resting upon *shale*.

To the N.E. of this village rises a Pass, which has an elevation of 15,247 feet, and here along its summit, where the streams which descend

Fig. 6.

Fig. 7.



N.B. The precise nature of these strata is undetermined from the impossibility of procuring access to them, but they appear to consist of Contorted Shales, and limestones surmounted by Sandstones.

No. 1. Bed of Spiti River. 2 Vertical strata. 3.3.3. Beds of debris and fragments from above.

from the snows have worn numerous channels through the loose and decomposing *shales*, occur the fossils which were long ago discovered by Dr. Gerard. These consist of various species of *ammonites, belemnites, orthoceratites arca*, and some others; but all partaking of the same decomposing nature as the *shales* in which they occur, so that it is next to impossible to procure a perfect specimen, or to prevent its falling to pieces if obtained.

The *limestones* which here alternate in the series, are sometimes wholly composed of shells, and are of a dark grey colour, while at the height of 14,712 feet occurs a bed of a whitish grey colour, and almost free from shells, but imbedding large rounded masses of various sizes, which when broken are found to be composed wholly of the dark shell *limestone* already mentioned.

Among these hills there is great confusion in the direction of the dip, the strata sometimes inclining to the S.W. or N. E., while at others they are N.N.W., and to almost every point of the compass. These masses are, however, generally limited to small extent, and appear like fragments torn from the true or main direction by the force of the upheaving agent. These strata extend along the range for many miles farther up the valley, but no fossils were apparent at any place, except on the heights above Leedung and Larra. They exist, however, in the form of shell *limestone* along the range immediately leading from the lake Chummorareel; but at this season the whole range lay so deeply buried in snow, that the route was impracticable, and I was obliged reluctantly to quit the fossil site, not half satisfied with its investigation.

From the nature of the rocks in this part of the valley, and the reports of those who have visited lake Chummorareel, I should feel strongly inclined to believe that it is situated among the *Lias clays*. Puttee Ram, the Tartar wuzeer, who has often visited the spot, assured me that the lake was surrounded by high hills composed of *earth* of various colours, red, yellow, blue, &c. and that the country around was all of similar *clays*, and not composed of rocks like the lower parts of Spiti, although sometimes above the hills of clay, large masses of stone were also found.

Such a description, all rough though it be, would lead one to expect the *Lias* beds resting on the red *marle*, and surmounted by the *sandstone* series above the *oolite*. The subject, I am sorry to think, must thus far remain obscure, until some more fortunate traveller shall venture upon those interesting scenes.

From this slight sketch it will be seen that the geological series from Kotgurh to the neighbourhood of Soongnum, in Kunawur, is that of the primary class; while thence, to the head of the Spiti valley, we find,